# A Comparative Study of Blood Sampling From Venipuncture and Short Peripheral Catheters in Pediatric Inpatients

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**ABSTRACT**

This prospective, comparative study examined blood test results, hemolysis rates, and patient perceptions related to 2 blood sampling methods in pediatric inpatients (N = 95). Blood specimens were drawn via venipuncture and a short peripheral catheter used for fluid administration. Results revealed no significant differences in potassium and glucose levels. No clinically significant difference in hemoglobin was noted. Hemolysis rates were 4% for venipuncture samples and 15% when drawn from peripheral catheters. One catheter became occluded after a blood draw. Patients/parents rated distress and dissatisfaction with venipuncture as significantly greater compared with short peripheral catheter blood sampling ($P < .001$).

**Key words:** blood sampling, pediatric inpatients, peripheral intravenous catheter, short peripheral catheter, venipuncture

Venipuncture for the collection of blood specimens is one of the most common procedures performed in hospitals, often occurring daily for inpatients.[1] Venipuncture is traditionally viewed as the most accurate means of collecting venous blood specimens.[2] However, inpatients characterize venipuncture as distressing and dissatisfying, causing both physical pain and psychological trauma.[2,3] Venipuncture can cause bruising, hematomas, vasovagal reactions, peripheral nerve injury, and iatrogenic anemia.[1,2]

Pediatric patients cite venipuncture as a significant source of pain and fear during hospitalization.[4,5] Acutely ill children are particularly vulnerable to the physical pain and psychological impact of venipuncture. Psychological trauma can arise from a sense of being powerless to help one's self when harm is inflicted. Experiences of painful procedures can be encoded in children's memories and stimulate anxiety about future medical procedures.[5] When pediatric patients resort to intense avoidance tactics, such as crying and resisting, venipuncture can be even more traumatic for

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the patient, family, and nursing staff and can result in an increased incidence of unusable specimens and subsequent delays in treatment. Pediatric pain from needlesticks needs to be managed proactively whenever possible.[5] This study aimed to explore the option of collecting blood specimens from short peripheral catheters (SPCs) with intravenous (IV) fluids infusing compared with venipuncture in a sample of pediatric inpatients.

## BACKGROUND

Venipuncture is considered the optimal way to collect usable blood specimens in hospitals.[2,6,7] Unusable blood specimens not suitable for laboratory analysis are attributed to 3 primary reasons. Hemolysis is the most common factor that renders blood specimens unusable for analysis.[8,9] Hemolysis occurs when cell membranes of the erythrocytes are damaged and hemoglobin and other intracellular components are released into the plasma.[8,10] The primary causes of cellular rupture are disruption of the cell membrane when the specimen is drawn, for example, through a small needle and agitation of the specimen during transport to the laboratory for analysis.[8,10] Hemolysis accounts for 40% to 70% of unusable samples.[8,9] A hemolysis rate of $\leq$2% is considered the best practice benchmark by the American Society for Clinical Pathology (ASCP). However, reported rates of hemolysis in routine samples worldwide often range from 3.3% to more than 75%.[10]

When blood specimens are hemolyzed and the concentration of intracellular components in the plasma increases, more than 30 types of blood tests cannot be accurately conducted, and the blood sample may have to be redrawn from the patient. Redrawing blood samples may result in treatment delays, which elevate hospital costs, increase patient and parent dissatisfaction, and can cause harm to the patient.[7,11-13] Furthermore, multiple venipunctures can cause vein depletion, thus compromising future access for blood sampling and treatments.[13]

A second prelaboratory cause of unusable specimens is the contamination of blood specimens by IV fluids or IV medication. Contamination accounts for approximately 2% to 4% of all unusable specimens sent for laboratory analysis.[11,14] Contamination is not an issue during venipuncture but can occur when blood specimens are drawn from SPCs if fluids and medication are infusing. Contamination can cause erroneous test results or delays in treatment, thus placing the patient at risk for poor outcomes. When specimens are contaminated, new samples must be redrawn from the patient.

A third cause of unusable blood specimens in the prelaboratory phase is inadequate volume of the sample. Inadequate volume can result if a vein is too small for blood to be withdrawn, a clot forms in the venipuncture device, or a patient resists and the blood collection process ceases before an adequate volume is obtained. Patient resistance most often occurs in pediatric populations due to the physical and psychological distress associated with venipuncture.[4,5] In a recent study of 100 SPCs in pediatric inpatients, an adequate volume of blood was withdrawn for diagnostic testing 76% of the time.[15] When adequate sample volumes are not obtained, it is necessary to redraw the specimen. Repeated venipunctures in pediatric patients due to unusable blood specimens are a source of high distress for patients and families.

An alternative to venipuncture is to draw blood samples from SPCs, either when the catheter is newly placed into the vein or after IV fluids and medications are infusing. Emergency departments (EDs) commonly draw blood samples from SPCs immediately after placement because specimens can be obtained quickly, with no risk of contamination from IV fluids or medications, and without requiring the patient to have another venipuncture.[16] Research suggests a possible increased risk for hemolysis when blood samples are drawn from SPCs immediately after placement.[10,17] The Infusion Nurses Society's *Infusion Therapy Standards of Practice* (the *Standards*) supports blood sampling for pediatric patients and selected adult populations from indwelling SPCs.[17] This evidence review primarily focuses on studies in which blood samples were drawn from SPCs used for the infusion of fluids or medications.

Clinicians often debate the risks and benefits of drawing blood specimens from SPCs with IV fluids infusing.[3,5,8,18] Frequently cited advantages are that the patient has fewer needlesticks and therefore less pain and psychological distress, health care staff have less exposure to blood and needlesticks, nursing staff expend less time and effort restraining resistant pediatric patients to obtain specimens, nursing staff experience less emotional distress from subjecting vulnerable patients to painful venipunctures, and specimens are generally obtained more quickly.[2,3] The risks of drawing blood specimens from SPCs are hemolysis of the specimen; contamination of the specimen when IV fluids or medications are infusing; and complications, including infiltration, occlusion of the catheter, displacement of the catheter from the access site, bloodstream infection, and phlebitis.[3,10,12]

Since 2006, the *Standards* has supported blood sampling from SPCs for adults with difficult venous access, patients with bleeding disorders, patients with a need for serial blood tests, and pediatric patients.[17,19,20] However, the adoption of this practice is far from universal, as debate continues about the risk-benefit comparison and the strength of the evidence that supports blood sampling from SPCs. Professional organizations, such as the Emergency Nurses Association and the Laboratory Medicine Best Practices Work Group, maintain that venipuncture is the best approach for collecting venous blood specimens. Furthermore, evidence is insufficient to derive a consensus on a detailed procedure for drawing blood samples from SPCs with IV fluids infusing. The professional dialog includes questions about how long to discontinue specific IV fluids

before beginning the blood sampling process, how much blood to discard before drawing the specimen, and how much flush solution to use after obtaining the specimen, if any.

## Literature Review

The research team conducted an initial literature review in 2006 and continued to update the literature review through early 2019. Databases included CINAHL, PubMed, Medline, Google Scholar, Ovid, and Cochrane Library; a review of reference lists in pertinent publications was also conducted. Fourteen research studies, 2 meta-analyses, and 1 systematic review were identified that directly or indirectly compared blood specimens obtained by venipuncture with blood specimens obtained from SPCs. One meta-analysis included 11 studies conducted between 1994 and 2011.[21] The second meta-analysis analyzed data from 15 studies conducted between 1996 and 2013.[11] In addition, a systematic review of evidence synthesized results from 8 studies conducted between 1996 and 2008 and made practice recommendations.[10] Adult inpatients composed the samples in 10 studies. Pediatric patients composed the sample in 3 studies. Two studies did not record ages of patients. Both meta-analyses focused on blood sampling in EDs. All were nonrandom samples, and no studies were highly controlled in design.

Seven studies with adult patients found significant statistical differences in blood test results between specimens collected by venipuncture and specimens collected from SPCs.[10,11,21-24] The meta-analysis by Heyer et al[21] ranked as *high* the evidence for drawing blood specimens solely by venipuncture based on 11 studies of patients of all ages. However, half of the 11 studies were evaluated by the authors as only *fair* in quality; of the studies the authors judged to be *good* quality, 3 were unpublished and 1 was published 25 years ago.[21] The meta-analysis by Lippi et al[11] recommended venipuncture only for blood sampling in the ED because of the risk of hemolysis in specimens collected from SPCs and the subsequent delay in treatment. Similarly, the systematic review by Halm et al[10] primarily considered studies conducted in EDs and made the recommendation that no blood specimens be collected from SPCs due to rates of hemolysis.

Conversely, 7 studies with adults and 3 with pediatric patients did not find conclusive, significant differences in blood test results between the 2 collection methods.[2-4,12,14,18,25,26] Most of these studies with adult participants occurred in an ED. A wide range of blood tests were examined in the studies, including glucose, potassium, sodium, serum chemistries, cardiac enzymes, coagulation tests, pH, venous blood gases, hemoglobin, and hematocrit. In a study of 257 samples from adults in an ED, specimens were obtained by venipuncture and from a saline lock where IV medications had been infused. Equivalent test results were found for blood chemistries, hematologies, and coagulation studies but not for venous blood gases and pH.[2] Similarly, a study of 272 paired samples from older adults on a short-stay unit in Spain did not find equivalency in venous blood gas values but did find acceptable equivalence in other common blood tests.[18] Not all of these 10 studies consistently reported whether IV fluids were infusing into the SPC at the time the blood specimen was collected.

One study with pediatric inpatients (N = 47) found no significant differences in a wide array of blood tests between the 2 methods of blood sampling, except for glucose. Glucose levels were higher when drawn from SPCs compared with venipuncture, most often when IV fluids contained dextrose.[3] No differences in hemolysis rates or SPC complications were noted between the 2 methods. This study found that pediatric patients experienced statistically significantly less crying and distress when blood specimens were drawn from SPCs.[3] A second study with pediatric inpatients (N = 80) revealed that blood samples could be easily drawn from SPCs without damage to the catheter or site and with little hemolysis.[4] These 2 studies with pediatric inpatients recommended drawing blood samples for basic chemistries and hematology from SPCs, with the exception of tests for glucose.

A third research study examined rates of hemolysis in blood samples of pediatric patients in an ED. Results revealed increased rates of hemolysis when blood specimens were drawn from a newly inserted SPC as compared with blood specimens drawn by venipuncture from pediatric patients in the same ED. Hemolysis rates were 16% for specimens drawn from SPCs and 6% when drawn by venipuncture. The SPCs had not been used for infusing IV fluids in this study.[27]

Given the small number of studies with pediatric patients and the mixed results from studies with adult samples, more research is needed to clarify the acceptability of collecting blood samples from SPCs in hospitalized pediatric populations. This line of research is especially significant as pain management becomes an escalating priority in acute care hospitals and error-free, timely treatment of patients remains a societal mandate.

## Aims and Objectives

The aim of this study was to compare outcomes from 2 methods of blood sampling in pediatric inpatients. The 2 methods were drawing blood by a traditional venipuncture process and drawing blood from SPCs into which fluids were infusing. Outcome measures include the degree of equivalence of the results of 3 blood tests, specifically potassium, glucose, and hemoglobin; frequency of SPC or access site complications; rate of unusable blood samples due to hemolysis, contamination, or an inadequate volume; patient/parent perceptions of distress and satisfaction related to the blood draw methods; and patient/parent preference of a method of blood sampling.

The objective of the study was to answer 6 research questions:

1. Is there a significant difference in blood test results for potassium, glucose, and hemoglobin between blood specimens drawn by venipuncture and those drawn from SPCs into which IV fluids are infusing?
2. Is there a significant difference in hemolysis rates in blood specimens drawn by venipuncture and those drawn from SPCs into which IV fluids are infusing?
3. Is there a significant difference in patient/parent satisfaction scores related to blood specimens drawn by venipuncture and those drawn from SPCs into which IV fluids are infusing?
4. Is there a significant difference in patient distress ratings related to blood specimens drawn by venipuncture and those drawn from SPCs into which IV fluids are infusing?
5. What is the preference of patients/parents for the method by which blood specimens are drawn?
6. What is the frequency of complications to the SPC or the access site when blood is drawn from an SPC?

## Theoretical Framework

Kolcaba's Theory of Comfort provided the guiding framework for this study.[28] Kolcaba[28] proposed that comfort was a basic human need that persons actively strived to meet. Kolcaba conceptualized comfort in 3 ways, as relief, ease, and transcendence, and proposed that comfort existed within 4 contexts, specifically physical, psychospiritual, sociocultural, and environmental. Kolcaba believed that nurses were empowered to assess for comfort and to tailor interventions to promote comfort. Comfort was the key outcome of autonomous nursing care.[29] When patients experienced 1 or more type of comfort in 1 or more contexts, patients perceived health care experiences and quality of life more positively.[28]

Clinical nurses must consider competing priorities related to blood sampling in pediatric patients. One priority is the patients' physical and psychospiritual comfort, which is promoted by blood sampling from SPCs and avoiding venipuncture. A recent study found that only 53% of attempts to cannulate a vein in pediatric patients in an ED were successful on the first attempt.[30] Nurses reason that, because almost half of the SPC placement procedures required more than 1 venipuncture, it is prudent to use an existing vascular access device to avoid further venipunctures. A second priority held is the physical comfort that results when disease processes are diagnosed and treated in a timely and accurate manner. This priority is best addressed by collecting usable blood specimens by venipuncture, in which the risks of contamination, hemolysis, low-volume samples, and IV catheter complications are minimized.

This study aimed to create new knowledge to guide nursing interventions that promote comfort for pediatric patients undergoing the collection of blood samples. The theoretical constructs of Kolcaba and DiMarco[31] apply not only to an individual patient but also to family members. Family members may experience relief, ease, and transcendence similar to patient experiences. Research findings suggest that parents may experience anxiety and psychospiritual trauma when children undergo painful venous access, as evidenced by functional imaging studies of parents' brains and parents' elevated heart rate and blood pressure.[8] If nurses can draw accurate, usable blood samples through SPCs rather than venipuncture, then hospitalized children and families may experience more ease.

Kolcaba[28,32] defined the concept of ease as calmness or contentment in the absence of distress. In this study, *ease* was defined as contentment and absence of distress related to the method of blood sampling during hospitalization. Ease was measured in 3 ways: (1) intensity of distress related to both methods of blood sampling as reported by pediatric patients or by a parent, if patients were unable to articulate perceived degrees of distress; (2) degree of satisfaction with both methods of blood sampling as reported by pediatric patients or a parent, if patients were unable to articulate degrees of satisfaction; and (3) patient or parent preference regarding 1 of the 2 blood sampling methods.

# METHODS

## Design and Sample

The study was a correlational 2-group comparative design. Participants served as their own controls and contributed 2 blood samples, 1 collected per venipuncture and 1 collected from SPCs used for infusion of IV fluids.

The setting for the study was a teaching hospital in the Midwestern United States. The 15-bed pediatric unit was staffed by registered nurses (RNs) who cared for approximately 600 patients each year.

A convenience sample of pediatric inpatients provided data for the study. Inclusion criteria were as follows: (1) aged 6 months through 17 years, (2) minimum weight of 16 lbs., (3) parent/guardian could understand English, (4) parent/guardian signed consent for child to participate in this study, (5) children $\geq$7 years of age signed an assent to participate when appropriate, (6) had a 24-gauge or larger SPC used for administering IV fluids, and (7) had a health care provider's order to obtain a blood sample for hemoglobin, potassium, and glucose levels. These 3 tests were selected because they were sensitive to hemolysis and contamination from IV fluids and IV medications.

Exclusion criteria included the following: (1) previous hemoglobin level below normal limits during this hospitalization, (2) maximum amount of blood volume drawn from the child for recent blood sampling,[33] (3) severe volume depletion, and (4) presence of a CVAD or other access for blood sampling that would replace venipuncture. The participation rate was 66% of the qualified pediatric patients who were invited to participate in the study.

A power analysis indicated that a sample size of 100 would yield a medium effect size, which would allow for estimating with confidence the magnitude of the difference between the outcomes of the 2 methods of blood sampling. Enrolled participants numbered 105; 95 had complete data sets and were included in this analysis. The significance level was set at .05.

## Ethical Review

The study was approved by a full board review through the institutional review board (IRB) of the hospital where it was conducted. Parents gave consent for children to participate. Parents were screened for literacy and competence. If parents were not able to read English, the study information and consent forms were read to them. If parents were not competent to give consent for the patient per nursing judgment, the patient was not enrolled in the study until the parents appeared competent to give consent. Children age ≥7 years were screened for literacy and provided signed assent to participate when able. If children aged ≥7 years were not able to read, the study information and consent forms were read to them.

Data were stored in a secure location accessible only by the members of the research team, per IRB guidelines. The research team planned to store the data for 3 years after the completion of dissemination.

## Instrumentation

In addition to the blood tests collected and analyzed, four 10-point visual analog scales (VASs) measured patient/parent satisfaction and patient/parent distress with the 2 methods of blood sampling. The anchor points for the satisfaction VASs were "not at all satisfied with how this blood sample was drawn" (1) and "very satisfied with how this blood sample was drawn" (10). The anchor points for the distress VASs were "no distress at all when this sample was drawn" (1) and "worst distress ever when this sample was drawn" (10).

The validity of VASs has been widely supported as perceptual measures in a variety of clinical contexts. A study of 106 children in an ED found that patients under the age of 9 years did not clearly understand the VAS.[34] Thus, in this study, if the patient was under the age of 7 years, a parent's perceptions of the patient's distress and satisfaction was recorded. Patients between the ages of 7 and 9 years had a voice, along with the parent, in determining the numerical responses for the VASs, if the child so desired. A single forced-choice item asked the patient's/parent's preference for 1 of the 2 methods of blood sampling. Demographic and clinical data were extracted from the patient's electronic health record.

## Data Collection

Six pediatric nurses were trained and evaluated as competent in following the study protocol. However, only 1 research nurse persisted in collecting data over time, and she enrolled >90% of the study participants. To obtain the target sample size, data were collected between 2008 and 2014.

Once a patient qualified for the study, parental consent was obtained, along with patient assent when indicated. The research nurse obtained blood specimens for hemoglobin, glucose, and potassium by venipuncture. Then the patient/parent completed the VAS for satisfaction and distress with venipuncture. No more than 10 minutes after the venipuncture, the research nurse drew blood for hemoglobin, glucose, and potassium from the SPC, following the procedure described in the study protocol (Table 1). Tourniquets were rarely used.[35] Patient/parent then completed the VASs for satisfaction and distress with blood sampling from the SPC and 1 item regarding preferred method of blood sampling. The SPC site was observed for 72 hours or until hospital discharge, with attention given to the development of phlebitis, occlusion of the catheter, or displacement of the catheter from the access site related to the research study protocol, as well as any occurrence of bloodstream infection.

All of the testing of blood specimens occurred at the target hospital laboratory. The research nurse obtained the results from the laboratory and recorded the data in an Excel file (Microsoft Corporation, Redmond, WA).

After the conclusion of data collection for the study, a poststudy monitoring phase began, lasting from 2015 to 2018. In this phase, the research study procedure for drawing blood from SPCs in pediatric inpatients was accepted as the standard of care on the target pediatric unit. The procedure, based on the 2006 *Standards,*[19] was congruent with the *Standards* released after the study started[20] and after the poststudy monitoring phase began[17] (Table 1). When a nurse elected to draw blood specimens from the SPC, all of the ordered blood tests except blood cultures were drawn from the SPC, whether IV fluids were infusing or the SPC was locked.

No comparative venipuncture data were collected during poststudy monitoring. No patient identifiers were collected. In the poststudy monitoring phase, nurses recorded data on the frequency with which laboratory test results were unanticipated in any way and therefore possibly erroneous, the frequency with which specimens had to be redrawn because of hemolysis, and the frequency of complications related to the SPC or access site, including bloodstream infections. This poststudy monitoring phase was significant because data collection was not limited to 1 research nurse. The procedure for blood sampling was available for all of the nurses on the pediatric unit to use, and many did. Furthermore, in the poststudy monitoring phase, blood samples were drawn not only for hemoglobin, potassium, and glucose, but for all of the ordered tests except blood cultures.

## Data Analysis

Data from blood test results, the 4 VASs, and the single item about patient preference were analyzed descriptively for means, frequencies, and percentages appropriate for the level of data. Paired *t* tests were computed to evaluate differences between the 2 methods of blood sampling. Cochran test of proportions was computed to determine differences in percentages of hemolyzed specimens. Correlations appropriate to the level of data were computed to determine interrelationships among study variables. Data analysis was conducted with SPSS software, version 18 (IBM Corporation, Armonk, NY).

**TABLE 1**

## A Comparison of INS Standards With the Study Procedure for Blood Sampling From a Short Peripheral Catheter

| Study Procedure for Obtaining Blood Specimens From an SPC Used for IV Fluid Administration (2008-2014 and 2015-2018) | INS Standards for Obtaining Blood Specimens from SPCs[a] (2016) |
|---|---|
| 1. Stop IV fluids infusing into the peripheral site for 1 to 2 minutes. | 1. Stop infusing fluids for at least 2 minutes. |
| 2. Flush catheter and extension tubing, if present, with 3 mL of 0.9% sodium chloride to ascertain patency. Be sure to note length of extension tubing and adjust flush amount accordingly. | 2. Not prescribed. |
| 3. Withdraw blood and waste 1-2 mL, according to the length of the extension tubing, before obtaining sample. | 3. Waste 1-2 mL of blood before obtaining sample. |
| 4. Withdraw blood specimen into vacutainers (preferred) or syringes that are then transferred into vacutainers. | 4. Not prescribed. |
| 5. Apply tourniquet lightly and briefly only if no blood can be withdrawn from the SPC. | 5. To avoid hemolysis and inaccurate test results, avoid use of a tourniquet. If one is necessary, apply for < 1 minute and release immediately when blood begins to flow into the container. |
| 6. After obtaining all blood specimens, flush SPC with an appropriately determined amount of 0.9% sodium chloride based on the catheter system and patient-related factors. | 6. Not prescribed. |
| 7. Resume IV fluid administration. | 7. Resume IV fluid administration. |
| 8. Follow all standard precautions and requirements for aseptic technique to prevent infection. | 8. Follow all standard precautions and requirements for aseptic technique to prevent infection. |

Abbreviations: INS, Infusion Nurses Society; IV, intravenous; SPC, short peripheral catheter.
[a]Data from Gorski et al.[17]

## RESULTS

Analysis of demographic data indicated that the sample was 52% female, with a mean age of 87 months and a range of 6 months to 17 years. The most common admitting diagnoses were gastrointestinal disorders (32%), respiratory disorders (21%), and infectious conditions (29%; Table 2). For two-thirds of the sample, the infusing IV solution was dextrose with 0.45% sodium chloride (NaCl) or 0.25% NaCl, with and without potassium added. One-third of participants had no dextrose in the IV fluid infusing into the SPC at the time of study participation. One third of the sample had venipunctures performed in the hand and two-thirds in the antecubital fossa. Likewise, one-third of the sample had the SPC placed in the hand or lower arm, and two-thirds had the SPC placed in the antecubital area. A total of 28.1% of SPCs had been in place for <1 hour when blood was drawn for study participants, and 50.1% had been in place <24 hours but >1 hour. Two-thirds of the sample had a 20- or 22-gauge catheter, whereas the remaining one-third had a 24-gauge catheter.

The mean time between venipuncture and drawing the blood specimen from the SPC was 5.7 minutes. All of the specimens were drawn using vacutainers except for one, when a syringe was used to precisely control the amount of blood sampled in a young patient. Tourniquets were rarely used to draw blood from SPCs during the study and the post-study monitoring phase. In this study, no significant differences between gender or age groups were noted related to blood tests results, hemolysis, or complications with the SPC or access site.

**TABLE 2**

## Sample Demographics

| Participant Characteristics (N = 95) | Data |
|---|---|
| Age in months; mean, SD (range) | 87.2, 62.3 (6-204) |
| Gender, n (%) | |
| Female | 50 (52.1) |
| Male | 45 (46.9) |
| Admitting diagnosis, % | |
| Abdominal/gastrointestinal | 32 |
| Respiratory | 21 |
| Infection (nonabdominal, nonrespiratory) | 29 |

Abbreviation: SD, standard deviation.

## RESULTS

### Research Question 1

To address the first research question regarding differences in values of potassium, glucose, and hemoglobin between the 2 methods of blood sampling, potassium and glucose levels were not statistically significantly different (Table 3). The inclusion of infusing dextrose did not significantly elevate glucose values in the blood specimens obtained from the SPC ($t = -1.29$; $P = .202$). Hemoglobin levels were statistically significantly different (Table 3). A case-by-case

**TABLE 3**

## Descriptive and Comparative Statistics for Study Variables

| | Mean | N | SD | Standard Error of the Mean | Paired Differences | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean Difference | SD | Standard Error of the Mean | *t* | df | *P* Value (2-tailed) |
| Hemoglobin | | | | | 0.48199 | 0.83529 | 0.08570 | 5.624 | 94 | .000[a] |
| Venipuncture | 12.2367 | 95 | 1.45532 | 0.14931 | | | | | | |
| SPC | 11.7547 | 95 | 1.53046 | 0.15702 | | | | | | |
| Potassium | | | | | −0.07433 | 0.62322 | 0.06328 | −1.175 | 96 | .243 |
| Venipuncture | 4.1855 | 95 | 0.70677 | 0.07176 | | | | | | |
| SPC | 4.2598 | 95 | 0.78973 | 0.08019 | | | | | | |
| Glucose | | | | | −2.54639 | 29.51060 | 2.99635 | −0.850 | 96 | .398 |
| Venipuncture | 102.5970 | 95 | 18.88985 | 1.91797 | | | | | | |
| SPC | 105.1443 | 95 | 31.81980 | 3.23081 | | | | | | |
| Patient satisfaction | | | | | −1.2738 | 2.5429 | 0.2775 | −4.591 | 83 | .000[a] |
| Venipuncture | 8.179 | 84 | 2.7426 | .2992 | | | | | | |
| SPC | 9.452 | 84 | 1.4006 | .1528 | | | | | | |
| Patient distress | | | | | 3.4573 | 2.9733 | 0.3284 | 10.529 | 81 | .000[a] |
| Venipuncture | 4.927 | 82 | 3.0257 | .3341 | | | | | | |
| SPC | 1.470 | 82 | 1.0011 | .1105 | | | | | | |

Abbreviations: *df*, degrees of freedom; SD, standard deviation; SPC, short peripheral catheter.
[a] $P < .001$.

review of the hemoglobin values was conducted by a team that included an experienced pathologist, statistician, physician, and medical laboratory scientist. The statistically significant variance in hemoglobin levels was within the acceptable margin of error set by the College of American Pathologists, with variations within 1 SD. The review team judged that the difference in hemoglobin levels between the 2 blood draw methods would not have altered the treatment plan for the patient and thus was not deemed clinically significant.

### Research Question 2

Hemolysis rates were 4% for blood specimens drawn by venipuncture and 15% for samples drawn from SPCs, a statistically significant difference (Cochran's Q = 9.308; $P = .002$). Hemolysis was only visible in 1 specimen, which was drawn by venipuncture. All of the other instances of hemolysis were determined by laboratory analysis. The percentages of hemolysis and hemolysis indices were not calculated by the laboratory during the time of the data collection. Of the 15 hemolyzed specimens drawn from SPCs, 6 were from 22- to 24-gauge SPCs placed in small veins, such as the hand and scalp.

### Research Questions 3, 4, and 5

Patient/parent satisfaction was significantly higher and perceived patient distress was significantly lower when blood specimens were draw from SPCs (Table 3). Higher scores indicated a greater degree of satisfaction and greater degree of distress. The range of scores on the VAS for satisfaction with venipuncture and distress with venipuncture was 1 to 10. The range of scores on the VAS for satisfaction with blood sampling via the SPC was 4 to 10. The range of scores on the VAS for distress with blood sampling via the SPC was 1 to 5. Younger participants reported higher distress with the venipuncture method ($r = -.25$; $P < .05$). Multiple venipuncture attempts were significantly related to lower satisfaction ($r = -.29$; $P < .01$) and higher distress ($r = .24$; $P < .05$). Patients (99%) preferred the SPC blood draw method. The 1 patient who preferred venipuncture was an adolescent male who remarked to the research nurse that he wanted to show he was "tough enough."

### Research Question 6

One SPC became occluded after drawing the blood specimen. No SPCs became dislodged, and no phlebitis or bloodstream infections were noted within 72 hours or before hospital discharge.

### Poststudy Monitoring Phase

During the poststudy monitoring phase, nurses on the target pediatric unit for this study could elect to use the study procedure for drawing blood specimens from an SPC. Data were recorded on 140 patients over a 3-year period. Analysis of outcome data revealed no instances of impairment of the SPC or the access site, no instances of

unanticipated blood test results, and no instances in which the blood sample needed to be redrawn due to hemolysis, suspected contamination, or other causes.

## DISCUSSION

The results of this study indicated that blood samples can be drawn accurately from SPCs in pediatric inpatients, with 2 considerations noted. Rates of hemolysis were higher in the samples drawn from SPCs as compared with venipuncture. Hemoglobin values were statistically significantly different between the 2 methods, but the differences were not clinically significant. Complications related to the SPC or access site were rare. Compared with venipuncture, blood sampling from SPCs is the method that patients and parents prefer, because it causes significantly less distress than venipuncture and is associated with significantly greater satisfaction.

### Comparing Blood Test Results: Equivalence and Contamination

The equivalency of the blood specimens drawn by venipuncture and from SPCs was consistent with findings from previous studies in adults and children.[2-4,12,14,18,25,26] The equivalent blood test results across the 2 methods of sampling indicate that there was little or no systematic IV fluid contamination of specimens drawn from SPCs. Similarly, in 2 studies of adults, potassium levels drawn by venipuncture and from SPCs were not significantly different when there was a 4- to 5-mL waste.[18,25]

This study found a statistically significant difference in hemoglobin levels between the 2 methods of blood sampling; however, the difference was not judged to be clinically significant by an expert team. Similarly, 1 study of adults in an ED found statistically significant differences in hemoglobin between specimens drawn by venipuncture and from a saline lock, but the research team did not find the statistically significant results to hold clinical significance.[2]

In a study of pediatric patients that compared blood specimens drawn by venipuncture and from SPCs with IV fluids infusing, the only significant difference was in glucose levels.[3] Specimens drawn from SPCs had significantly increased glucose levels compared with specimens drawn by venipuncture, especially when the infusing IV contained dextrose.[3] The research team concluded that basic hematology and chemistry tests could be accurately collected from SPCs but not glucose.[3] Findings in a small study with adults (N = 5) suggested that drawing blood specimens from SPCs into which an IV containing dextrose was infusing could affect not only glucose levels but also electrolytes, including potassium and especially sodium.[36]

In contrast, the results of this study showed no significant differences in glucose values when specimens were drawn by venipuncture or from SPCs, even when IV fluids with dextrose were infusing. Likewise, there was no difference in potassium levels between the 2 methods of blood sampling in this study. One difference between this study and the findings from Berger-Achituv et al[3] is that the procedure for this study called for the infusion to be stopped for 1 to 2 minutes. In the Berger-Achituv et al[3] study, the infusion was only stopped for 30 seconds.

One factor in the equivalency of the blood test results in this study was that 1 research nurse collected 90% of the data, using the same precise technique each time. Previous studies have suggested that the skill of the personnel drawing the blood specimens can influence the usability of the specimens,[6,8,35,37] although not all studies agree.[12,27] In the poststudy monitoring phase, many nurses drew blood for varying types of blood tests from the SPC, and there was no record of any unanticipated results, suggesting that the accuracy of the specimens collected from SPCs can remain acceptable under less controlled conditions.

A method for evaluating the presence or absence of contamination does not exist.[36] Although contamination of blood specimens with fluid from the infusion is infrequently found in research studies, small degrees of contamination could be present and undetected, which may or may not influence clinical treatment plans. Equivalent values for potassium and glucose in this study offer reassurance that large degrees of contamination were not present but do not guarantee the complete absence of contamination.

### Comparing Blood Test Results: Hemolysis Rates

Hemolysis rates in this study were higher for samples drawn from SPCs, a finding consistent with results in previous studies.[6,10,23,27] Hemolysis rates were above the ASCP benchmark of 2% for both methods of blood sampling in this study. Hemolysis is typically increased when a tourniquet is used,[21,35] catheter size is less than 22-gauge,[21] and/or veins are small, as with pediatric patients.[10] Placement of SPCs in the antecubital space reduces the risk of hemolysis.[7,21,37] A study of vein placement for SPCs in 67 adults found that blood drawn from SPCs placed distal to the median and cephalic veins are likely to hemolyze compared with blood drawn more proximally. The hemolysis rate overall in the study was 30%.[38] This study cautioned against drawing blood samples from SPCs in the metacarpal plexus attributed to erythrocyte disruption secondary to pressure gradient changes among small veins, larger SPCs, and the blood collection tube.[38] The development of new knowledge, such as this evidence on vein location, can help nurses reduce rates of hemolysis when placing SPCs and collecting specimens from SPCs. In this present study, more than one-third of the hemolyzed samples were drawn from small-gauge catheters placed in the scalp, foot, or in the arm distal to the antecubital fossa of pediatric patients. Nearly two-thirds of the SPCs and venipunctures in this study were in the antecubital fossa, which may have contributed to the lower hemolysis rate compared with other studies.

Additional factors that increase the risk of hemolysis are associated with specimen transport to the laboratory and

time to analysis. Hemolysis is more likely when laboratory analysis of a specimen is delayed.[39] This study did not measure time from blood draw to laboratory analysis. All of the specimens in this study were sent to the laboratory promptly via a pneumatic tube system. Three previous studies have investigated the impact of sending specimens to the laboratory through a pneumatic tube on hemolysis without conclusive results.[10,40,41]

The ASCP standard of ≤2% hemolysis in venous blood samples is set high to encourage clinicians to reduce hemolysis rates to support accurate and efficient diagnosis and treatment of patients. However, the appropriateness of this benchmark has been debated, and the evidence base for it has been questioned.[7,42] The competing priorities in the debate are the "perfect blood draw" and "minimal patient discomfort."[42] Some EDs and inpatient units for both children and adults have adopted higher benchmarks for hemolysis that seem reasonable and more achievable.[43-45] The range of hemolysis rates in the studies included in this evidence review was 0.5% to 77.0%. Only 2 studies claimed to be at or below the ASCP benchmark, and 1 of those studies acknowledged that a rate <2% could not be sustained.[6] In 1 meta-analysis, none of the studies reported rates of hemolysis at or below the ASCP benchmark when blood specimens were drawn from SPCs.[21] It is possible that higher rates of hemolysis are unavoidable in acutely ill pediatric patients, if prevention of pain is a goal of the patient experience. In this study, if the option of obtaining blood specimens from SPCs was not available to these 95 children, 80 of them would have been punctured needlessly for blood tests, because the blood could have been drawn successfully from the existing SPC. Likewise, 140 patients in the poststudy monitoring phase would have experienced unnecessary venipuncture and discomfort.

### Poststudy Monitoring Phase

The finding of no unanticipated blood test results and no need to redraw unusable specimens on 140 pediatric patients supports the appropriateness of collecting blood specimens from SPCs and the effectiveness of the staff education in performing the procedure. The poststudy data extend the study findings in several ways. For example, the data were provided by multiple different RNs, not just 1 research nurse, because all of the pediatric RNs had the option of using the new procedure. In addition, the data reflected results from all of the ordered blood tests, not just potassium, glucose, and hemoglobin. These results suggest that nurses with varying experience and skill levels can draw a variety of blood tests accurately from SPCs without hemolysis and contamination and without disrupting the SPC site.

When the poststudy monitoring plan began, it became hospital procedure for the staff member drawing blood specimens to immediately roll the vacutainer by hand as soon as it filled with blood to avoid clotting of the specimen. This step may have contributed to the absence of any samples recorded as unusable in the poststudy period.

Nurses on the pediatric unit were not required to use the SPC blood sampling method in the poststudy monitoring phase, although most did use the SPC approach at least occasionally. Not all of the nurses recorded all relevant data, often reporting that they were too busy. The poststudy data documented the sustainability of this practice over time.

### Patient/Parent Perceptions

The results of this study overwhelmingly reflected patient/parent preference for the SPC method of blood sampling over venipuncture. Both levels of distress and degree of satisfaction with the blood draw experience were significantly different, favoring the SPC method. A similar finding was noted in a study of pediatric patients who demonstrated significantly less crying and distress when blood specimens were drawn from an SPC compared with venipuncture.[3] Furthermore, this present study substantiated statistically what other studies have suggested,[21,46] that multiple needlestick procedures are a significant source of patient/parent distress.

### Catheter and SPC Site Complications

Only 1 incidence of SPC occlusion was noted, related to drawing blood specimens through it. This finding is nearly identical to the findings from 2 recent studies in which blood sampling occurred through 100 SPCs and 150 SPCs, respectively, in hospitalized pediatric patients. In both studies, only 1.0% to 1.3% of the SPCs became nonfunctional after drawing a blood specimen. Fear of occluding the SPC or dislodging the SPC from the access site when collecting blood specimens is unfounded if appropriate procedures are followed and access sites are properly secured.[13,47]

### Theoretical Perspectives

This study did not test a proposition from Kolcaba's[28] theory; rather, the theory provided a context for the study and for nurses' role in making clinical judgments with high regard for patient comfort. Given the distress that patients report from venipuncture, it may be prudent to accept a higher rate of hemolysis to draw blood specimens from SPCs and improve the patient experience. In this study, 85% of the specimens were usable. No critical delays in treatment or adverse outcomes were reported.

Nurses on the pediatric unit of the target hospital now have an Infusion Nurses Society–supported option for preventing pain and promoting ease during hospitalization. Not every nurse draws blood specimens from existing SPCs on every patient every time. Nurses seem to weigh a multitude of factors when evaluating the possibility of obtaining a pain-free, usable blood specimen from an SPC. Future research may explicate nurses' decision-making processes and lend more insight into how nurses translate theory and evidence into practice and what new knowledge nurses need next.

## LIMITATIONS

The study limitations included conduction at a single site with a convenience sample and no randomization. The results of this study cannot be extrapolated to adult patients,

because only pediatric inpatients and their parents provided the data for this study. This study only compared the results of 3 common blood tests, so the results cannot be generalized to all possible blood tests. However, the poststudy data monitoring included any and all ordered blood tests, except blood cultures; no instances of unanticipated results were documented. This study did not examine the handling of specimens after retrieval, the process by which specimens were transported to the laboratory, or time that a tourniquet was in place if any, all factors that can contribute to hemolysis.[37,48] High scores on VAS items that measured satisfaction and distress with venipuncture could have been influenced by the fact that the research nurse drew the specimens, then provided the VAS items, and was typically present when patients or parents completed the VAS items. Patients/parents may not have wanted to report dissatisfaction that could have reflected negatively on the research nurse. An additional limitation is that, by nursing judgment, nurses on the unit where the study was conducted could implement comfort measures during venipuncture, such as topical anesthetic cream or spray, vibration, distraction, pacifiers, and glucose water for young infants. Data on comfort measures were not collected and could have influenced patient/parent perceptions.

### Implications for Practice and Recommendations

This study aimed to develop new knowledge to guide nurses who want to maximize the accuracy and timeliness of diagnostic blood tests, as well as provide for patient comfort. Obtaining blood specimens from SPCs into which IV fluids are infusing can be considered as an option in pediatric inpatient populations, as recommended by the *Standards*.[17] A decision-making flowchart could guide nurses' decision-making regarding a method for blood sampling, especially in recognizing factors that create high risk for hemolysis when drawing specimens from SPCs. To reduce contamination, nurses must give careful attention to stopping an infusion for a sufficient length of time and withdrawing an appropriate amount of blood to discard before drawing a specimen. Nurses should be watchful for new evidence that may extend key principles for blood sampling procedures. In a future research endeavor, this study can be modified and conducted as a randomized control trial, with each participant assigned randomly to a blood draw method, rather than all participants experiencing both methods of blood sampling. In addition, future study can examine the efficacy of new needleless devices that can draw venous blood samples from selected SPCs through a tubing system that reduces blood exposure and may further reduce the incidence of hemolysis.[1]

Nurses can continue to weigh the evidence and consider drawing pediatric blood specimens from SPCs, especially if the patient is not at high risk for hemolysis. For example, if a hospitalized pediatric patient is 12 years old with a 20-gauge SPC placed in an antecubital vein and routine blood chemistries and hematology tests are ordered, an RN may make the decision to collect the blood specimen from the SPC. Conversely, if a pediatric patient is 2 years old, easily resistant, has an uncertain diagnosis and a wide array of blood tests ordered, and has a 24-gauge SPC in the hand, the RN may decide that venipuncture offers the least risk despite the discomfort and dissatisfaction. Similar to previous research on the development of a tool to predict the degree to which vascular access will be difficult in children,[49] future research may develop a predictive tool for determining when drawing from an SPC is likely to be successful.

## CONCLUSIONS

Blood levels of potassium, glucose, and hemoglobin drawn by venipuncture and from SPCs in pediatric patients were not significantly different, statistically and/or clinically. Significantly more hemolysis occurred in blood specimens drawn from SPCs, a finding comparable to hemolysis results in previous research with pediatric and adult patients. Patients or parents preferred the SPC blood draw method, reporting significantly higher satisfaction and less distress.

The procedure for the study and the poststudy monitoring phase closely paralleled the procedure for blood sampling from an SPC as addressed in the *Standards.*[17] Among study participants, no complications of phlebitis, bloodstream infection, or SPC dislodgment occurred. The only complication was the occlusion of 1 catheter. Poststudy monitoring of 140 blood sampling procedures on pediatric patients in the same unit where the research study took place revealed no unanticipated laboratory tests results from contamination and no need for blood specimens to be redrawn.

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